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Examining the Effects of Electronic Mentoring Prompts on Learners' Scientific Reasoning Skills in a Text-Based Online Conference for a Science Education Course

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ABSTRACT: In a science education methods course, groups of students were initially involved in a face-to-face discussion and were sensitized about certain conflicting claims regarding a puzzling observation or set of observations. They were then instructed to resolve their conflicting ideas through electronic discussion. Students had two weeks time to participate in the online discussion by posting their points of view as well as replying to others' postings using the asynchronous discussion feature of WebCT. Students discussed these claims, and conducted more experiments, whenever they felt they need, in order to reach consensus about their opposing claims. The online discussion was anonymous in order to encourage students' participation in dialogue and negotiation of meaning. It was thus possible to identify students' alternative frameworks and attempt to facilitate conceptual change and understanding. The instructor of the course participated in the online discussion as a student by asking challenging questions. Students were supposed after participating in the online discussion to reach consensus and individually email their answers to the instructor. The data analysis provided ample evidence of students' patterns of thinking and their difficulties to be involved in evidence-based argumentation and reach valid conclusions acting as "practicing scientists" by forming and testing relevant hypotheses.

KEYWORDS: Asynchronous communication, conferencing tools, electronic prompts, e-moderating, hypothesis testing, online discussion.

Introduction

Research evidence suggests that the existing curricula and the dominant teaching practices are far from achieving basic science literacy. "Teaching emphasizes the learning of answers more than the exploitation of questions, memory at the expense of critical thought, bits and pieces of information instead of understanding in context, recitation over argument, reading in lieu of doing" (American Association for the Advancement of Science, 1990, p. xiii). Curricula are overstuffed and undernourished, and the demands for coverage do not allow students to work together, share ideas and information, or to design and conduct experiments, be involved in problem-solving activities, and extend their intellectual capabilities.

Reforms in science education always advocate the development of students' scientific reasoning, understanding of the nature of science, and the development of scientific "habits of mind" (National Research Council, 1996). Reasoning is central to scientific practice, because scientists form hypotheses, collect evidence, construct evidence-based arguments, and consider alternative perspectives and explanations in decision making. Argumentation is also a central part of the socially constructed nature of scientific inquiry.

Due to classroom time constraints, scientific reasoning is often omitted from classroom practices (Newton, Driver, & Osborne, 1999). Student teachers also lack knowledge about the process of scientific reasoning and the formulation and testing of hypotheses. Thus, there exists a pressing need to engage all prospective teachers in rich activities, so that they become able to use scientific reasoning and argumentation in science teaching and learning. Moreover, prospective teachers usually have a particular mind-set when taking a science methods course. They simply want to learn how to teach, and only about how to teach, and anything they perceive as deviation from that goal is of secondary interest and importance. In this study, there was a deliberate attempt to shift from positioning the teacher in the role of learning how to teach to situating the teacher in the role of learning how to learn science. This shift is not simplistic and it can have profound results on developing prospective teachers' content knowledge and pedagogy and especially their pedagogical content knowledge (Shulman, 1986) or, for the specific research, their information-communication-technology related pedagogical content knowing (Valanides, & Angeli, 2005).

Asynchronous online conferencing systems also have the affordances to remedy for the lack of adequate classroom time, and offer new opportunities for supporting learning. These systems are often text-based and can be used as tools to promote learner collaboration and support the inquiry process (Duffy, Duebber, & Hawley, 1998). These systems provide a forum in which discussion can occur outside the classroom and allow the instructor to observe students' contributions to a discussion, participate in a discussion, model reasoning skills, and interject questions and comments in order to scaffold students' reasoning within their zone of proximal development. Online conferencing systems also allow students to contribute to a discussion at a time and place that are most convenient to them, participate even anonymously in the online discussion, and thus express their thoughts freely. Since time and place constraints are removed, all students can participate in the discussion. Since students have more time, they more carefully consider and provide evidence for their claims and provide deeper and more thoughtful reflections.

Often times in higher education, online conferencing systems are used in combination with face to face instruction, and this type of learning is known as blended learning (BL), because it combines two types of learning environments, a face-to-face learning environment and a computer-mediated learning environment.

Thus, the purpose of this study was to design a blended learning environment for a science education methods course for the purpose of promoting students' sci-

entific reasoning skills. More specifically, the study attempted to gain insights about students' understanding of the process of forming and testing hypotheses and related concepts (i.e., observations and their explanations, predictions, evidence and conclusions), and to evaluate their argumentation skills, as they were involved in an online discussion trying to confirm or refute several hypotheses.

A Framework for Promoting Scientific Reasoning Skills

Scientific reasoning in science education involves engaging learners in thinking to decide what conclusions are or are not sanctioned by the evidence from a science experiment, generating plausible alternative explanations of an observation, or weighing the evidence and evaluating the argumentation regarding the merits of a technological innovation. Thus, an approach for developing learners' scientific reasoning skills is concerned less with students accumulating undigested facts and scientific definitions and procedures, than with students learning to think scientifically. As students learn to think scientifically, they inevitably do organize and internalize facts, learn terminology, and use scientific procedures (Paul, 1995). Traditional practices in science teaching rarely call students upon to understand the reasons for doing an experiment or for doing it in a particular way. Typical science texts do not even ask students to conduct an experiment for answering a question. Science texts usually tell students how to conduct experiments and what particular controls to use. Also, the link between observation and conclusion is rarely made. Moreover, many science texts use the concept of "scientific method" in a misleading way. For many, the scientific method simply means to run several steps of a procedure mechanically. Learning from a science activity, however, requires that students understand its purpose and should allow students to ponder questions, propose hypotheses, and develop and conduct their own experiments.

In the context of text-based online conferencing systems, a moderator can provide students with support in the form of written prompts although we do recognize that this type of support may become extremely time consuming. Research by Chinn and Brown (2000) has shown that contextualized prompts can indeed promote deep learning such that students are more apt to explain their reasoning and thoughts. Also, research by Herrenkohl, Palinscar, DeWater, and Kawasaki (1999) has shown that making scientific thinking strategies explicit to students can facilitate their understanding and use of these strategies. Research findings also showed that content-specific prompts helped students to better explain their reasoning in a particular context and content area. Other researchers (e.g., Kuhn & Udell, 2001; Kuhn & Udell, 2003) have focused on general prompts independent of the content area. For example, Kuhn and Udell (2003) used content-free prompts such as "generate reasons," "support reasons with evidence," and "examine and evaluate opposing perspectives." The results in this area of research showed that both content-specific and generic prompts promote different aspects of learners' reasoning skills. Therefore, in our instructional framework for promoting scientific reasoning we used both generic and content-specific prompts as shown in Tables 1, 2, and 3.

Table 1
Types of Prompts for Promoting Conceptual Understanding in Science

Type of Question Prompt	*Examples*
Clarification	• How does this concept explain the behaviour of this phenomenon? • What principle did you use to form your hypothesis? Why did you use this principle? • How did you apply the principles here?
Elaboration	
• Eliciting explanations	• Explain why you designed this experiment. • Explain why you think this experiment will work. • Explain the findings.
• Elaborating thoughts	• What will it happen if you do not control for these variables? • Why are you applying the same principle as before?

Table 2
Types of Prompts for Promoting General Thinking Skills

Type of Question Prompt	*Examples*
Understand the problem	• Do you understand what the problem is? • What is relevant here? • What information is missing? • What do you think are the important factors of this problem?
Generate solutions	• Develop possible solutions from different points of view.
Develop the reasoning for each solution	• Did you use logic or evidence to support the reasoning?
Decide which solution is best	• Give reasons why you think the solution you have chosen is best. • Are these reasons adequate? • Use evidence or logic to support your reasons. • Is there reason to doubt the evidence? • Consider the main alternatives to your solution and explain why your solution is better.

Table 3
Types of Prompts for Promoting Science-specific Processes

Type of Question Prompt	*Examples*
Form a hypothesis	• What are your assumptions? • What is your hypothesis?
Design an experiment	• How can we tell you are right? What experiment do you need to conduct? • Why are you designing this experiment? • What data do you need to collect to prove your hypothesis?
Collect and record data	• How are you going to collect data? • How are you going to record your data?
Interpret results	• Why did this happen? • What if we change 'this' to 'that?' How can you explain the new results? • How are these interpretations different? Do they share anything in common? • Could we explain these results another way?
Draw conclusions	• How did you get from that observation to that conclusion; • Is there supporting evidence for your conclusions?

Methodology

Subjects

Data were collected in the fall semester of 2005. Forty-seven preservice teachers, who were enrolled in a science education methods course, participated in the study. Students were required to participate in 13 whole-class meetings and in 13 75-minute lab sessions (about 15 students in each lab). For the lab sessions, students were working in groups of three.

The Science Methods Course

The science methods course was a compulsory course for prospective primary school teachers taken prior to student teaching. During the course, students were introduced to the use of hypothetico-predictive arguments in the context of testing hypotheses about several experiments. They also performed experiments involving the testing of hypotheses, where the proposed causal agents were observable (i.e., effects of the amount weight or the length of a pendulum on its speed of swinging). In these cases, the cause (independent variable) can be directly sensed and hypothesis testing involves its manipulation. Students were also engaged in discussions about the meaning and the differences of terms related to scientific reasoning, such as, observations, explanations of the observations, hypotheses, predictions, planned tests, evidence/data, and conclusions.

Thus, it was exemplified, discussed and practiced that the process of formulating and testing hypotheses is one of the core activities of scientists, and a critical component of scientific reasoning. A hypothesis usually relates to tentative explanations for a puzzling observation or a set of observations. For a hypothesis to be useful, it should suggest what kind of evidence would support it and what evidence would refute it. A hypothesis that cannot in principle be put to the test of evidence may be interesting, but it is not scientifically useful (AAAS, 1989, p. 27). Obviously, once a hypothesis is formulated, it is tested by the construction of an "if/ and /then argument," and the use of evidence in a hypothetico-predictive fashion. In very simple terms, for example, if differences in swing speeds are caused by differences in the amount of weight hanging on pendulums, and the weights are varied, while holding other possible causes (i.e., the length of the pendulum) constant, then pendulum swing speed should vary. This in reality frames a planned test that can provide evidence in support or against the stated hypothesis. Thus, when the planned test is actually carried out, the evidence does not support the stated hypothesis leading to the conclusion that weight differences do not cause changes in the swing speeds of a pendulum.

The students were repeatedly involved in similar activities and performed a number of different experiments, where they were asked to form a hypothesis and a consequent prediction, and then suggest a test for collecting evidence supporting or refuting the hypothesis. For example, they formulated and tested hypotheses about the effect of the length of a pendulum on the pendulum swing speed, or the factors affecting the evaporation of liquids (i.e., temperature, kind of liquid).

In a later lab session, students were asked to use a pan with a candle, stuck in the middle of the pan in the upright position, and to pour some water in the pan.

The students were then asked to discuss in groups and provide the best prediction they could about what would happen if a cylinder would be inverted over the burning candle and placed in the water. Then, each group of students, without performing the experiment, was asked to present to the whole class their ideas. This way, students became sensitized about conflicting claims regarding the experiment.

Later, they were instructed to perform the experiment, make careful observations, and record them, so that they could present them in class. After presenting their observations in class, conflicting points of view about their observations persisted, and students seemed puzzled and uncertain. Students' initial observations were more or less incomplete, while they could not differentiate between observations and the explanations of these observations. The basic differences in their observations related to the initial level of water in the inverted cylinder, the escape of bubbles from the bottom of the cylinder, and the way the level of water in the cylinder was changing. There was also confusion between observations and their explanations and, in most cases, students did not distinguish between observations and their explanations. Using the specific experiment, students were given specific examples about the difference between observations and their consequent explanations. For example, the flame of the candle went out (observation), but why this happened (explanation), or the level of water in the cylinder rose (observation), and what caused the water to rise (explanation)?

After clarifying students' questions but without providing any explanations, the students were asked to perform the same experiment several times until they resolved any differences related to their "objective" observations. They were specifically instructed to make as careful observations as possible trying to resolve their differences, while emphasis was put on the idea that "observations are not totally neutral." During this phase, there was a deliberate attempt to resolve any differences related to students' observations by repeating the experiment as many times as it was needed, in order to unanimously agree on the same "objective" observations. The purpose of this attempt was to finally accept the same observations, so that the students would try to provide explanations to them.

These face-to-face activities and discussions constituted the initiation phase of the study. Due to classroom time constraints, an asynchronous online conferencing system was then employed using WebCT, and students from each lab session (about 15 students in each lab) were asked to start as a group an online discussion. The instructor posted initially a welcome message to the students and instructed them to start using the asynchronous discussion feature of WebCT and familiarize themselves with its affordances. Students faced some difficulties to register in the online conferencing system, and it took them some time to fully understand the process of online discussion and several of the functions of WebCT.

When the students felt comfortable with the asynchronous discussion feature of WebCT, the instructor summarized the burning-candle experiment in WEBCT, and gave students directions regarding their contributions to the online conference. Thus, students from each lab session were asked to start as a group an online discussion in order to provide the best answer and full justification for the experi-

ment (i.e., to justify why the level of water rose after the experiment). Students were instructed to post messages discussing their point of view regarding the experiment, reply to other students' postings, provide evidence-based arguments, conduct additional experiments when this was considered necessary, and help each other in giving the best explanation. The online discussion was anonymous and remained open for two weeks. At the end of the two week period, each student had to individually email the course instructor a message explaining their evidence-based arguments regarding the explanation of the observed rise of the water level in the cylinder (Why did the flame go out and why did the water level in the cylinder rise?)

Results

Students' Alternative Hypotheses

In each group, there were sub-groups of students who formulated different competitive explanations (hypotheses) for the observed rise of water in the cylinder, but were unable to finally accept one of the alternative explanations as the best and valid one based on evidence. Only four of these competitive hypotheses will be discussed here. The most popular hypothesis among the students was related to the idea that oxygen is consumed by the burning candle, and the water is rising to fill the partial vacuum that is created. In this hypothesis, students failed to take into consideration that the burning candle was also producing other gases occupying space as well, that there were also bubbles moving from inside to outside the cylinder indicating that air escaped out the bottom of the cylinder, and that there was a difference in the temperature and the pressure of the air inside the cylinder.

Other students proposed that the burning candle converts oxygen to carbon dioxide and attributed the rise of water in the cylinder to the property of carbon dioxide to dissolve in water more easily than oxygen, resulting again in partial vacuum that is finally occupied by the rising water. In this case, students took into consideration the production of other gases by the burning candle, but they also neglected the escape of air (gases) out the bottom of the cylinder and the difference in pressure of the air inside the cylinder due to temperature fluctuation.

A less popular hypothesis stated that the flame causes the air around it (inside the cylinder) to expand and escape out of the bottom of the cylinder. Thus, after the flame goes out, the air cools, air pressure inside the cylinder is reduced, and the water is pushed in the cylinder due to the greater pressure outside the cylinder. Obviously, students who supported this hypothesis took into consideration both the escaping air (gases) out the bottom of the cylinder and the fluctuation in the temperature, and the pressure of the air in the cylinder. Only few of these students took into consideration the transformation of oxygen into carbon dioxide (or the other products of the burning candle as well).

A much less popular hypothesis suggested that the flames cause the water temperature to rise and, consequently, the water expands into the cylinder. Obviously, this hypothesis focused on the thermal expansion of water and failed to take into consideration other relevant information either observable (i.e., escape of air out of the bottom of the cylinder) or hypothesized based on common knowledge (i.e.,

transformation of oxygen into carbon dioxide or the pressure fluctuation of the air inside the cylinder due to differences in temperature).

New Experiments as Scaffolds

Once groups of students formulated multiple alternative hypotheses, they were challenged to support their claims using evidence from the experiment, or even to design and conduct new experiments and collect additional evidence supporting or refuting their favorable hypothesis. The instructor himself suggested, at a later stage, some experiments to be performed in an attempt to challenge students' ideas, and encourage the use of evidence-based arguments in supporting or refuting their explanations about the rise of water inside the cylinder. Some of these experiments will be briefly described in an attempt to clarify the kind of evidence that could be used to scaffold students' ideas and trigger new arguments on behalf of them.

(a) Use two burning candles side by side and compare the results with the case of the-one-burning-candle experiment: The specific experiment was proposed to challenge students' ideas who supported the hypothesis that the burning candle consumes oxygen creating partial vacuum that causes the water to rise inside the cylinder. In such a case, repeating the experiment using two burning candles will cause the water to rise at the same level. Obviously, in the second experiment, the same amount of oxygen will be consumed, the candles will go out faster, the rise of the water will be faster, but it will rise to the same level. After performing the experiment, the water will rise much higher than before (when using just one burning candle). It was thus expected that the students will realize that the evidence does not support their initial hypothesis and try to revise their thinking based on evidence.

(b) Repeat the previous experiment with much more water in the pan: This experiment was proposed as a test of the hypothesis that CO_2 dissolves more easily in water than O_2 and thus partial vacuum is created causing water to rise inside the cylinder. The main idea was that when more water is added in the pan, while holding other possible causes constant (planned test), then the amount of dissolved carbon dioxide in the water will be more, the partial vacuum will increase, the internal pressure will be reduced more, and thus the level of water in the cylinder will rise higher than previously. This prediction does not take into account other factors (i.e., the increase in hydrostatic pressure) and it is not confirmed by the outcome of the experiment (the water level does not rise higher than previously or the water level could be lower in the cylinder than in the pan, depending on the level of water in the pan that increases the hydrostatic pressure and may prevent the escape of bubbles out the bottom of the cylinder). It was thus expected that the evidence from the experiment will contradict the stated hypothesis creating the need for a revised (or totally new) hypothesis and a new attempt for testing it.

(c) Heat the cylinder from outside rather than using burning candles: If the heat from the candle(s) causes air to expand and finally escape out of the

bottom of the cylinder, then the same thing will happen if the cylinder is heated from the outside. Heating the air inside the cylinder either from inside (the flame of the burning candle) or from outside will cause the air to expand and some air will escape. Later, when the flame goes out or when heating from outside stops, the air inside the cylinder cools, air pressure inside the cylinder is reduced and the greater air pressure from outside causes the water to rise inside the cylinder. The outcome of this experiment provides confirmatory evidence to the stated hypothesis, although new predictions and tests may be needed. For example, additional evidence (confirmatory or contradictory) can be collected by heating from outside or from inside (using two or more burning candles) more intensively. Heating from outside (or from inside more intensively) will cause higher temperature inside the cylinder, more air to escape, and, after stopping the heating, as the air cools more water will rise inside the cylinder.

(d) Heat the pan of water rather than using burning candles: The hypothesis that the burning candle causes the water temperature to rise and the water to expand into the cylinder leads to the idea that heating the water from below the pan (bowl) will also cause expansion of the water inside the cylinder. This prediction will not be confirmed by the experimental results and thus students should examine carefully their hypothesis, taking into consideration the collected evidence. They may also decide to carefully examine whether the burning candle in the first experiment causes any increase in the water temperature.

The outcomes of the new experiments initiated new discussions and trigger shifts in students' thinking (a kind of paradigm shift). New competitive claims and interesting new discussions started. Students attempted to compare their views prior and after any new experiment. The discourse transcripts and students' individual messages sent to the course instructor constitute the data of the study that are extensive and very rich.

Students' Knowledge and Reasoning Abilities

Preliminary analysis of students' emailed answers to the question posed by the instructor and the transcripts of their online discussions indicate that almost all the students had a good declarative knowledge of hypothesis-testing tasks, but they faced a lot of difficulties in correctly applying the required knowledge in specific tasks, where unobservable variables were involved. For example, they faced difficulties to understand that, after inverting the cylinder over the burning candle and placed in the water, the level of water inside the cylinder will be lower than in the pan. Obviously, they failed to understand that water occupies space inside the cylinder and thus air decreases its volume and increases its pressure that becomes higher than the normal atmospheric pressure outside the cylinder. They also faced difficulties to control the amount of air (oxygen) each case they repeated an experiment, and could not even conceptualize proposed solutions. More specifically, when the students were asked to repeat the experiment with the burning candle, they did not even consider it necessary to first empty the CO_2 from the cylinder, before repeating the experiment using the same cylinder. In most cases, they were

repeating the experiment with the cylinder full of CO_2 and had difficulties to understand why the outcomes of the repeated experiment were different than previously. Even, when they were specifically reminded that "the flame went out, because the burning candle transformed the O_2 in the cylinder into CO_2," they did not know what to do in order to replace it with air. These difficulties seemed to be totally related to the kind of "memorized knowledge" they had about certain phenomena. Thus, they had difficulties to understand that atmospheric air is lighter than CO_2 and that they should hold for some time the cylinder upside down, and not upright, so that CO_2 could be replaced by the lighter air. Nevertheless, they proposed to first full the cylinder with water and then to empty it, so that the CO_2 inside the cylinder will be replaced by air, and then to somehow dry the cylinder. This kind of thinking was more easily understood, because, at the intermediate stage, the cylinder was full of water that was later replaced by air as soon as the water was poured out the cylinder.

Similarly, when students were asked to compare the final level of water inside the cylinder when using one or two burning candles side by side, they also faced difficulties to understand that the amount of air (oxygen) in both experiments should be the same (a controlled variable). Obviously, two similar candles put under the upside down cylinder occupy more space and replace double air than just one candle. Thus, students had difficulties to understand why it was necessary for controlling the amount of oxygen (air) to put the two candles side by side, and perform first the experiment with only one candle burning, and then repeat the experiment with both candles burning. Only then, they could attribute the higher level of water inside the cylinder, after each experiment, to the number of burning candles rather than to the different amount of air (oxygen) inside the same upside cylinder.

Obviously, there was a discrepancy between their declarative statements and their real understanding of the scientific phenomena. Performance differences also seemed to be related to the abstractness of the hypotheses being tested and the complexity of the justifications involved in testing them. Many topics taught in secondary school and university classes involve unobservable theoretical entities and processes (i.e., atoms, molecules, and their movements/collisions) that increase the abstractness/ complexity of the topics and their cognitive load. Processing the necessary information becomes then difficult not only because totally abstract thinking is needed (Piaget's formal operational reasoning), but also because limited cognitive resources remain available, due the restricted capacity of working memory (Chandler & Sweller, 1991).

Besides, there was evidence indicating that pre-service teachers hold a number of alternative conceptions that persist and extensively influence their reasoning patterns. Thus, students' preconceptions (alternative conceptions) seemed to be one main source of students' difficulties in testing hypotheses. It was thus really astonishing to identify a small number of students insisting that the burning candle will not go out, because "water consists of O_2 and H_2 and it can thus preserve the flame. Similarly, many more students insisted that there existed either a sucking or a pulling force that was responsible for the rise of the level of water inside the cylinder (Lawson, 2002).

In the process of hypothesis testing, preliminary results indicate that students were not consistent in generating sound arguments to test their hypothesis. In most cases where unobservable entities were involved, they could not easily differentiate among observations and their explanations, hypotheses and predictions, observed results and conclusions. In their planned tests and their written reports, there also exhibited a "verification bias," and failed to revise their hypotheses even when the evidence contradicted the hypothesis they were testing. They also exhibited arguments that, in most cases, were unsatisfactory. An argument was considered as satisfactory, if it included a hypothesis, a prediction, a planned test, and a conclusion based on observed results. The main categories of unsatisfactory arguments were those that were based on persisting (mis)conceptions, had missing or confused elements, failed to take into consideration all the available evidence, indicated a rather hasty generalization, failed to consider multiple hypotheses or alternative explanations, proposed predictions that did not follow from their hypothesis and the planned tests, and their conclusions were not based on evidence. These difficulties were prevalent and widespread whenever the hypothesized causal relationships involve non-observable entities, and increased complexity or abstractness. In these cases, correct performance appeared to equate Piaget's formal operational reasoning that did not seem to be fully developed for this group of prospective teachers.

The instructor-moderator facilitated the online conference systematically and posted 249 messages during the two-week time. Of the 249 messages, 151 of them were prompts for promoting science-specific processes (see Table 3), 43 of them were prompts for promoting conceptual understanding in science (see Table 1), and the rest of them were general thinking prompts (see Table 2). These results indicated that student teachers lack a sound understanding of the nature of important science inquiry processes, such as hypothesis testing and evidence-based argumentation, and thus most of the e-moderating strategies targeted the development of these scientific processes.

Conclusions and Implications

Preliminary results from the present study send a really alarming signal. It seems that most of the prospective primary school teachers, who were about to complete their preservice education, had many persistent alternative conceptions and experienced widespread difficulties in designing controlled experiments, in differentiating among hypotheses, predictions, observed results and conclusions in the process of hypothesis-testing. These difficulties were more prevalent when hypothesis-testing involved an abstract causal agent (independent variable). Thus, the evidence from the present study corroborates previous research conclusions that the existing curricula and the dominant teaching practices are far from achieving basic science literacy, and that sstudents' previous science courses, either at the university level or previously, did little, if anything, to develop their reasoning capacities.

Interestingly, the participants did not pay appropriate attention to the process of hypothesis testing and rushed to hasty generalizations, based on what they

learned, and their previous deep-rooted and persistent alternative conceptions. On the contrary, to test a hypothesis a planned experiment must be performed, so that observed results can be compared with a prediction based on the stated hypothesis. The tendency to underestimate or even neglect observed results coupled with students' inconsistent use of some key terms related to hypothesis testing (hypothesis, prediction, observed results etc) and their prevalent verification bias, constitute a serious problem. Given that hypothesis-testing lies in the heart of scientific reasoning, this problem needs further attention. It seems that the problem is rooted not only in the teaching approaches, but relates to textbooks and curriculum materials as well.

The current emphasis on teaching science as hands-on inquiry process, the focus on explicating the nature of science, and the important role of argument in developing students' understanding of the nature of science and, probably, for the public understanding of science is an important step in the correct direction. This direction emphasizes that it is time to shift the central point of education "to teach people to think, to use their rational powers, to become better problem solvers" (Gagne, 1980, p. 85), and informed and active citizens in a complicate society.

Nevertheless, given the joint constraints of class time available and the number of students in each class, opportunities for meaningful discussion and collaborative learning are extremely limited. The use of conferencing tools and other affordances of modern technologies provide unique opportunities towards achieving some of these goals and blur the distinction between face-to face and distance learning environments. More specifically, asynchronous discussion environments afford us enormous pedagogical opportunities that allow to move beyond transmitting information and testing for facts and procedures, and to demand intellectual rigor and to improve students' abilities to test hypotheses and their evidence-based argumentation skills in distributed environments, like the one that was used in the present study.

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